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Articles

The Neonatal Integrative Developmental Care Model: Seven Neuroprotective Core Measures for Family-Centered Developmental Care

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ABSTRACT

Neuroplasticity refers to the ability of the brain to make short- or long-term modifications to the strength and number of its synaptic neuronal connections in response to incoming stimuli associated with activity and experience. Neuroplasticity is a lifelong property of the human brain, which peaks during early life during the period of most rapid brain growth. The Neonatal Integrative Developmental Care Model uses neuroprotective interventions as strategies to support optimal synaptic neural connections, promote normal development, and prevent disabilities. Seven neuroprotective core measures for family-centered developmental care of the premature neonate are addressed: healing environment, partnering with families, positioning and handling, minimizing stress and pain, safeguarding sleep, protecting skin, and optimizing nutrition.

The management of premature infants has advanced over the past three decades to the point that infants born as early as 22 weeks' gestation now have a chance of survival because of a multitude of technologic advances. This progress comes with great physical, emotional, and financial costs because premature infants spend many weeks and months in the neonatal intensive care unit (NICU). Because development continues outside the protective environment of the womb for the prematurely born fetus, many have impaired short- and long-term outcomes.[1,2]

These tiny patients are at a high risk for a variety of developmental problems including motor impairments, cognitive deficits, poor academic achievement, and behavioral disorders.[3]

Although physical and motor disorders may be more noticeable, increasingly more focus is being directed toward the mental health issues that children born prematurely or at low birth weight are at higher risk for attention-deficit, attention-deficit-hyperactive, anxiety, and other emotional disorders[4–7]. A significant proportion of prematurely born children show behaviors consistent with autism.[8–11] Although causes of these findings remain unclear, it is thought that early stressful environmental influences on the brain during critically sensitive developmental periods may contribute to these adverse outcomes,[12] a concept that is supported by much animal research.

Neonatal Behavioral Development and Protection

The fetal neurologic system is in a highly active stage of development during the third trimester of gestation. With volumes of research documenting long-term disabilities in prematurely born children, understanding how we can better support the preterm infant's fragile neurologic system can pave the way to decreasing the negative effects of fetal development occurring within the extrauterine environment of the NICU and help to minimize these impairments.[13–15]

Support must begin with the adoption of a conceptual framework and philosophy of neuroprotective family-centered, developmental care. The pioneering work by Sameroff, Brazelton, and Als[16] found that assessing the individual infant's ability to cope with excessive stimulation provides the caregiver with information to modify each infant's environment and treatment strategies. When preterm infants were assessed and provided with developmentally supportive individualized care, Als[17] saw significantly improved outcomes including fewer days on the ventilator, earlier feeding success, shorter hospital stay, a marked reduction in the number of complications, and improved neurodevelopmental outcomes during the first 18 months of life, findings that were sustained to 8 years of age.[18]

Neuroprotection has been defined as strategies capable of preventing neuronal cell death.[19] *Neuroplasticity* refers to the ability of the brain to make short- or long-term modifications to the strength and number of its synaptic neuronal connections in response to incoming stimuli associated with activity and experience. Neuroplasticity is a lifelong property of the human brain, although it is most prominent from birth until late childhood. It is thought that neuroplasticity peaks during early life because it is a period of rapid brain growth with the

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generation of excessive new synapses (synaptogenesis) and the activity- and experience-dependent pruning of synapses. Neuroprotective strategies are interventions used to support the developing brain or to facilitate the brain after a neuron injury in a way that decreases neuronal cell death and allows it to heal through developing new connections and pathways for functionality.[20] Neuroprotective interventions that promote normal development and prevent disabilities include organizational, therapeutic, and environment-modifying measures such as family-centered developmental care.[21] Neuroprotective interventions are outlined in Appendix A.

Models of Developmental Care

Developmental care models are not new, dating back to Florence Nightingale in the19th century with her theory on the importance of the nurturing healing environment for the patient's restoration of health.[16,17,22] Her focus was on the importance of a clean, well-lit, well-ventilated environment to provide the patient health and improve outcomes.[23] The concept of healing environments suggests that the patient's surroundings can make a difference in how quickly the patient recovers and that patients experience a more positive outcome in an environment that incorporates natural light, elements of nature, soothing colors, meaningful and varying stimuli, peaceful sounds, pleasant views, and a sense of beauty.[24]

The impact of the NICU environment on the infant's developing brain became evident to health care providers in the 1970s.[25,26] Als' “Synactive Theory,” building on the earlier work of Brazelton,[25] interpreted the developmental process to be based on neurodevelopmental subsystem interaction between a neonate's internal functioning, the environment, and caregivers. The theory proposes that, at any given time in development, various subsystems interact with the environment. When there is imbalance within one subsystem, all other subsystems are affected.[16,25]

The Universe of Developmental Care Model (UDC) is a more recent reformulation of neonatal developmental care theory. This model was introduced in 2008 by Gibbins et al[27] and portrays a patient- and family-centric environment within the health care universe. It expands on the Synactive Theory with the concept of a shared surface interface, portrayed as the skin forming a link between the body/organism and environment in which care is rendered and received. The UDC approach recognizes the interactive link between all developing systems and the caregiver/family while simultaneously providing a practical basis for formulating individualized patient care plans within the NICU's complex technological environment with emphasis on assessment and documentation.[28]

Since their inception earlier this decade, the US Centers for Medicare and Medicaid Services' core measures of quality control have been becoming increasingly influential in shaping health care delivery. Not only are hospitals required to report performance on the core measures to The Joint Commission (TJC), many also use those reports internally to drive clinical excellence. Future reimbursement will be closely linked to clinical performance and the core measures.

In addition, TJC has launched what it calls "The Joint Commission's Core Measure Solution Exchange” to facilitate a process where higher-performing hospitals can mentor lower-performing hospitals. This is a voluntary option where hospitals can access a Web site to both post and search for information.[29] It is anticipated that accreditation will soon be linked to core measures, and hospitals not achieving at least 85% compliance may be given a requirement for improvement (RIF).[30] Compliance to core measures has been a low priority for management and medical staff leadership; however, if “less-than-targeted” performance results in a requirement for improvement, these organizations will need to raise the bar in their performance. Improving patient care and creating benchmarks as standards of quality are increasingly becoming a priority in health care.

The Joint Commission has been successful in identifying opportunities to improve disease management and reduce mortality by using core measure sets. Using the TJC model of disease-specific core measures that are related to specific medical conditions, Coughlin et al[31] proposed five developmental care core measures that are focused on care actions, which are disease-independent yet essential to promote healthy growth and development of the preterm infant and family. The developmental care core measures included the following: (1) protected sleep, (2) pain and stress assessment and management, (3) activities of daily living (positioning, feeding, and skin care), (4) family-centered care, and (5) healing environment.

The Neonatal Integrative Developmental Care Model, described in this article, was developed to simplify aspects from the UDC and has incorporated essential concepts from the Core Measures of Neonatal Developmental Care.[31] The core measures are depicted as overlapping petals of a lotus to demonstrate the integrative nature of developmental care.[22]

To provide more practical guidance for NICU staff in delivering developmental care to preterm infants in the NICU, the five neonatal core measures first introduced by Coughlin et al[31] have been recategorized and expanded into seven distinct family-centered developmental core measures of neuroprotective neonatal care. This expansion enables additional focus on developmentally appropriate positioning and handling, optimizing nutrition and feeding, and protecting skin, all areas that are fundamental to providing developmental neonatal care. The seven neuroprotective core measures for family-centered developmental care described in the Neonatal Integrative Developmental Care Model include the following: (1) healing environment, (2) partnering with families, (3) position and handling, (4) safeguarding sleep, (5) minimizing stress and pain, (6) protecting skin, and (7) optimizing nutrition (see Fig 1).

Neurologic Development

To better understand the developmental problems associated with prematurity and other high-risk events, it is essential to understand the basics of neurosensory development of the neonate.

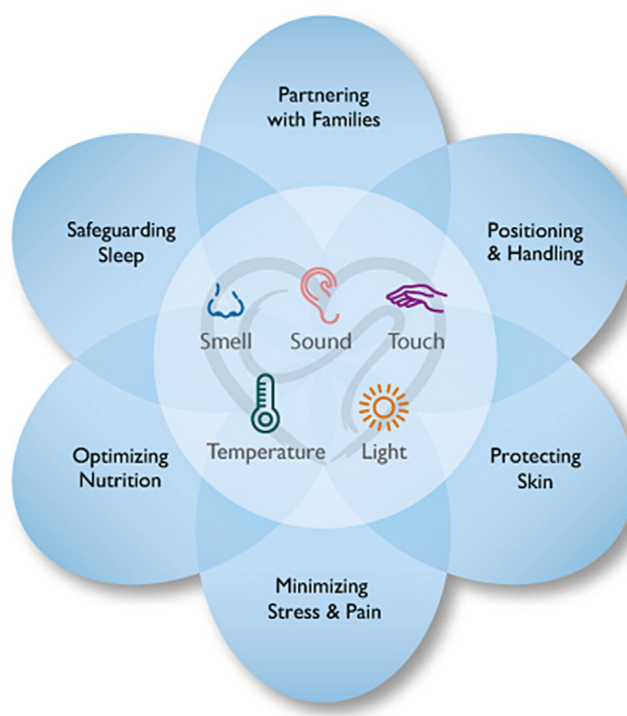

Fig 1. Neonatal Integrative Developmental Care Model (Philips Mother and Child Care).

The neurologic and sensory systems do not exist as separate entities but are interdependent and comprise the neurobehavioral and neurosensory development of the infant. Every sensory experience is recorded in the brain, leading to a behavioral response, thereby leading to yet another sensory experience. This cyclic interdependent action and reaction is the basis for neurobehavioral and neurosensory development.

The brain is the portion of the central nervous system (CNS) that receives messages and interprets, integrates, and organizes them and sends out messages to produce motor, language, or emotional responses.[32] Neurologic development begins in the third week of gestation with the formation of the neural plate, neural folds, and neural tube. Once the tube is formed and becomes a closed system, different regions of the brain begin to develop. At 4 weeks' gestation, the brain differentiates into the forebrain, midbrain, and hindbrain. The forebrain translates input from the senses and is responsible for memory formation, thinking, reasoning, and problem solving. The midbrain functions as a relay station, coordinating messages to their final destination, whereas the hindbrain regulates the heart, breathing, and muscle movements. At 7 weeks's gestation, the brain has the first detectable brain waves. By weeks 9 to 11, the basic brain structure is complete and brain mass increases rapidly.[33]

As these different regions of the brain begin to form, the development of the CNS is characterized by the following distinct overlapping processes: neuronal proliferation, neuronal and glial cell migration, organization, and myelination. These processes, especially organization and myelinization, continue past birth.[34]

There are three distinctive layers of the brain that develops as the brain matures: the brainstem, limbic system, and cerebral cortex.[35] The brainstem (medulla, cerebellum, pons) is first fashioned around the 33rd day of gestation and is nearly complete around the seventh month of gestation.[36–38] The brainstem receives sensory messages and relays the information to the cerebral cortex. It processes vestibular sensations necessary for hearing, balance, vision, and focusing attention.[35] It also regulates autonomic functions of internal organs, such as breathing, heartbeat, and digestion.[32,36]

The limbic system is involved in the regulation of autonomic and endocrine function as well as setting the arousal state. It is integral for the formation of long term memory, governing emotions, and it is closely associated with olfactory structures.

The cerebral cortex (cerebrum) is known as the cognitive brain and performs the most complex organizing of sensory input. The cerebral cortex is highly specialized and contains specific areas for dealing with voluntary functions in the body.[36,37] Although the neurological system is one of the earliest systems to develop in the embryo, it is not fully matured until adulthood.

The nervous system can be divided into areas of function that include autonomic, sensory, motor, and state regulation. Autonomic function includes self-regulation of respirations, heart rate, blood pressure, temperature, and nutritional intake. The infant must adapt and respond to many changes simultaneously to survive the extrauterine environment after birth.[34,39] Although autonomic regulation is usually mature enough for the full-term infant to adapt successfully after birth, the preterm infant often requires assistance.

Development of the sensory system occurs in a precise order that optimally should not be altered. Tactile senses (touch) develop first, then vestibular (proprioception), followed by olfactory (smell), gustatory (taste), auditory (hearing), and visual (sight) senses. Motor function is the result of maturation and coordination between neurodevelopment and muscular development. *State regulation* refers to patterns of sleep and arousal that begin in utero and continue after birth. As the infant matures, sleep and arousal cycles and transition patterns change in a highly individualized manner.

Both the structural development and the functional development of the brain are shaped by the influence and interaction of several major factors. These include genetic endowment, internal, endogenous, or hormonal stimulation and external experiences from the environment that stimulate the sensory organs. Brain architecture, cell differentiation, cell migration, initial cell location, and response to early stimulation are primarily directed by the genes or genetic endowment. Outside stimulation from the environment can influence or alter the expression or effect of genes through a process called *epigenetics*.

Although initial stimulation of each sensory system is internal or endogenous, at a critical or sensitive point in development, external stimulation and experiences are needed for further development. Experiences that influence fetal, infant, and child development can come from their physical, sensory, chemical, nutritional, social, and/or emotional environments. Events and stimuli from any of these components of environment are capable of altering the course and outcome of developmental processes producing changes in brain development that can be either positive or negative.[40]

Sensory Integration

The maternal womb, or intrauterine environment, is conducive to positive sensory input, which is crucial for normal brain development in a growing fetus. The intrauterine environment protects the developing fetus against harsh outside stimulation while providing a variety of tactile, vestibular, chemical, hormonal, auditory, and visual sensory stimuli in an integrated, multimodal fashion.[41] The intrauterine environment is characterized by limited light and noise exposure, normal sleep cycle development, and unrestricted access to mother via somatosensory, chemosensory, and auditory pathways.[42] The uterine wall provides secure boundaries for generalized flexion and gentle, secure containment for the developing fetus. Vestibular and tactile stimuli come from maternal and fetal movements and from contact with warm amniotic fluid, body parts, and the walls of the uterus. Hormonal cycles of the mother provide rhythmic and cyclical stimulation. All nutritional needs of the fetus are met via the placenta. Auditory input includes maternal voice, bowel sounds, blood flow through the placenta and umbilical cord, and filtered sounds from the extrauterine environment, transmitted through liquid and solid media.

In contrast, prematurely born neonates are exposed to fluctuations in temperature, touch, vestibular, gustatory, olfaction, noise, light, oxygen, and nutrients, which are very different from those they have experienced in utero. These negative sensory inputs replace the positive sensory inputs into the developing brain, which can permanently alter normal brain development. Events, stimuli, and environmental factors can either support the processes of sensory development or create significant interference. The developing brain is extremely sensitive to the appropriate levels of sensory stimuli, and alterations can result in abnormal structural and functional development of the brain. Sensory interference may occur when immature sensory systems are stimulated out of turn or with inappropriate stimuli, which could contribute to the behavioral, cognitive, and functional deficits, which many premature infants manifest.[43]

Babies of low or very low birth weight (VLBW), many of whom are also small for gestational age, are at increased risk for auditory and visual impairment including sensorineural hearing loss and deficits in visual acuity, color vision, and contrast sensitivity. In addition, long-term alterations in retinal function, subtle deficits in neural conduction in visual or auditory pathways, and a reduction in the startle response, which is thought to indicate the ability of the CNS to filter out extraneous stimuli, have all been demonstrated.[44–46]

When an infant is born prematurely, the still-developing brain and sensory systems are affected by the continuous interplay of stimuli in the NICU. It is essential that background neurosensory stimulation be kept at a level such that sensory systems can discriminate and accommodate meaningful signals or stimulation. This observation is especially true for touch, position, sound, light, and comfort, which are part of early neurosensory development whether it occurs in utero or in the NICU.[47]

The full-term healthy infant usually has a consistent nurturing caregiver and, with 40 weeks of intrauterine development, is ready for a variety of sensory experiences including tactile, vestibular, olfactory, gustatory, auditory, and visual. Normal patterns of motor control, cognitive learning, and adaptation are formed when appropriate sensory information is experienced in developmentally expected ways.

On the other hand, a premature infant typically has numerous caregivers and is exposed to high levels of inappropriate sensory input that can alter adaptation patterns. To better understand the correlation of early environmental factors to the developmental problems associated with prematurity, it is essential to examine the environment in which these infants spend a critical period of their development.

Core Measure 1: Healing Environment

The first neuroprotective core measure described in the Neonatal Integrative Developmental Care Model is the "Healing Environment." The healing environment encompasses the physical environment of space, privacy and safety, and the sensory environment of temperature and touch, proprioception, smell, taste, sound, and light. The NICU is where an extraordinary period of growth and development will take place for premature infants. Because the infant is no longer protected in the uterus, the physiologic and neuroprotective needs have dramatically changed.

The physical environment involves not only space but also characteristics of space, which affect position, movement, and motor development. The sensory environment includes the exposures and experiencing of temperature and touch, position and movement, smell and taste, hearing and noise, vision and light. Environmental sensory insults can result in lifelong alterations in brain development and function.[40] The chemical environment includes both nutritional and toxic exposures. Factors from the chemical environment are capable of having not only direct effects on the fetus or infant but also epigenetic effects that alter gene expression.

Physical Environment

Creating and monitoring a healing physical environment involves issues related to space, privacy, and safety. *Toward Improving the Outcome of Pregnancy*, published in 1976 by the March of Dimes,[48] was a landmark publication written by a multidisciplinary committee to provide a rationale for planning and policy for regionalized perinatal care, as well as details of roles and facility design. Sixteen years later, in 1992, a multidisciplinary NICU Committee, under the auspices of the Physical and Developmental Environment of the High-Risk Infant Project, reached consensus on the first edition of recommended standards for NICU design.

The purpose of this committee was to provide health care professionals, architects, interior designers, state health care facility regulators, and others involved in the planning of NICUs with a comprehensive set of minimum standards based on clinical experience and an evolving scientific database. The intent was to optimize NICU design within the constraints of available resources, to facilitate excellent neuroprotective developmental health care for the infant in a setting that provides adequate space and facilities to support the central role of the family as described in the Family-Centered Care model, and to meet the needs of the NICU staff.[49]

Attention is given to the NICU configuration: the location within the hospital, minimum space, clearance, and privacy requirements for the infant space. Family, staff, administrative, and general support space is delineated. Attention is also focused on illumination guidelines (ambient and natural lighting, individual and procedural lights) and acoustical guidelines (floor, wall, ceiling surfaces). Electrical, gas, mechanical, isolation, ambient temperature and ventilation recommendations likewise are outlined in the recommended standards.

Specific guidelines around single-family rooms are addressed. Single-family rooms allow improved ability to provide individualized and private environments for each baby and family when compared to multipatient rooms or pods. Caring for infants in individual private rooms in a NICU, in contrast to the open-bay environment, has led to improved infant outcomes.[50] The single-room NICU is a strategy that could address many environmental safety concerns and minimize negative iatrogenic effects by reducing the risk of infection and stress on the preterm infant. Decreased hospital-acquired infections, increased job satisfaction, and improved team support are some of the documented benefits from single-room NICU's.[51] The single-room NICU is a strategy that could address environmental concerns and minimize iatrogenic effects by reducing the risk of infection and stress on the preterm infant. The latest recommendations are now used worldwide and are available at www.nd.edu/~nicudes.[52]

Sensory Environment

Creating and monitoring a healing sensory environment involves issues related to thermoregulation, tactile, vestibular, olfactory, gustatory, auditory, and visual sensory systems of the neonate.

Temperature/Touch/Proprioception

As the newborn moves from a fluid-filled warm intrauterine environment to a dry cool environment, a major goal of neonatal care is to provide a neutral thermal environment in which an infant is neither gaining nor losing heat at the expense of energy expenditure. The sensory environment of the NICU (macroenvironment) should incorporate the following factors:

- Temperature 72°F to 78°F (22°C–26°C)
- Humidity 30% to 60%
- Air exchange six per hour (two with outside air exchange)
- All air filtered at 90% efficiency

To enhance the development of the preterm infant or infant weighing less than 2500 grams, additional attention must be paid to the infant's bed space (microenvironment) to support the infant's immature thermoregulatory system. The optimal environment for any newborn, but particularly for the premature infant, is skin-to-skin contact with mother (or father), also known as *kangaroo care*. In a process termed "thermosynchrony," the temperature of mother's chest has been shown to increase by 2°C to warm a cool infant in skin-to-skin contact and decrease by 1°C to cool an overheated infant. Being in skin-to-skin contact with mother meets the premature infant's needs for touch in the most natural environment possible outside the womb and also supplies needed proprioceptive sensory input to the infant's developing brain.

When the parents are unavailable for skin-to-skin holding or it is not possible, attention should focus on thermoregulation of the infant's individual bed space. To maintain a constant central temperature within narrow limits (36.5°C–37.5°C), VLBW or premature infants should be cared for in either incubators or radiant warmers.[53] The trend in neonatal care has been toward the use of dual-function infant incubators. The dual functions available in these incubators are the radiant warmer mode (open-type incubator) and the incubator mode (closed-type incubator). This new technology allows for care of a critically ill premature infant in a highly humidified environment (incubator mode), which can then be switched to the radiant warmer mode during a treatment or procedure, or for family space. These high-tech incubators (available through Philip's Healthcare [Monroeville, PA] and GE Healthcare [Laurel, MD]) are designed to provide the benefits of a neutral thermal environment, decrease insensible water loss, and permit easy access to infants while providing optimal protection from environmental stimuli.[53]

Positioning an infant in a midline, flexed, and contained position with the assistance of therapeutic positioning aids and swaddling decreases the surface area of the infant exposed to environmental air, thus reducing radiant and convective heat losses. This flexed and contained position offers additional temperature stability for the infant by minimizing extraneous movement and energy expenditure.[53]

Smell/Taste

The olfactory system is functional by 28 weeks' gestation.[54] Olfaction (smell) is initiated by neural excitation in response to specific molecules in the immediate surroundings. Olfactory information is transmitted directly from the nose to the cerebral cortex. Maternal odor influences neonatal behavior.[28] A mother's scent has been found to facilitate state regulation and optimal feeding experiences for both term and preterm infants. Because olfaction is functional in the second trimester, sensory stimuli from the NICU environment rather than the mother may interfere with its development, as well as other sensory development and attachment.[55]

Providing supports for mothers and infants to be together early in the NICU stay is essential in supporting the olfactory and gustatory sensory development. Providing odor and taste of the mother's milk has been shown to facilitate the infant's mouthing, sucking, arousal, and calming from irritability, especially in preparation for oral feeding.[56,57] Giving infants a pacifier with mother's milk has been shown to increase nonnutritive sucking, intake, and growth and to shorten the length of hospitalization.[58–60] Providing multisensory experiences such as combining odor and taste can potentiate sensory organization during feeding. Holding the baby close to the caregiver's body serves to provide this organized multisensory environment.[61]

Neonates' sense of smell is stimulated primarily by unpleasant odors. A variety of odorous products such as cleaners, skin preps, antibiotics, and alcohol (wipes and hand gels) are often present in the typical NICU environment. In addition, the neonate is often exposed to perfumes or aftershave worn by staff members. Infants may respond to noxious olfactory stimuli with altered respirations, transient apnea, and/or an increased heart rate.[62] Bartocci et al.[63] found that the smell of NICU detergent, once detected by the neonate, elicited a response that decreases cerebral blood flow to the right hemisphere of the brain.[63]

The emotional content of odors is highly plastic and can be modifiable by a few hours of exposure to odorous substances provided by caregivers. Because smells are processed by the same part of the brain that handles memories and emotions, it has been shown that people can recall a scent with 65% accuracy after 1 year.[54]

Protecting the infant's olfactory environment can be achieved through the use of olfactory neuroprotective interventions, which may include providing positive olfactory experiences such as maternal breast scent via a breast pad, soft cloth, or a Snoedel (Philips Children's Medical Ventures, Monroeville, PA). The Snoedel incorporates pure sheep wool into the high-quality flannel doll, which absorbs and slow releases the parents' scent. Skin-to-skin contact helps to support the discrimination of maternal breast scent. Oral care provided with breast milk helps the infant recognize the mother's smell and the taste of her milk and associates that smell with food and feeding when the infant is ready for oral feeds.

Staff should not wear perfume, cologne, or aftershave in the NICU. Skin preparation or skin care products that are unscented and fragrance-free should be used whenever possible.[28,64] Alcohol wipes should not be opened near an infant's head but, rather, outside the incubator environment. When cleaning hands with alcohol solution or foam, staff should wait a few seconds for the cleanser to dry before placing hands inside the incubator near the baby's face. Cleaning products used in the NICU should be unscented and fragrance-free. Laundry services should also use unscented products. The odor of tobacco on caregiver bodies and clothing as well as the odors of dry cleaning chemicals should be avoided.[65] It is important that staff be educated on this topic to prevent negative olfactory experiences and/or overstimulation.

Sound/Noise

At birth, ears are capable of discerning more than 300 000 sounds. The brain processes sounds a thousand times faster than images and registers sounds even during sleep. The constant bath of noise affects everything from concentration to health. The word *noise* comes from nausea, the Latin word for sickness. Excessive noise levels in the NICU can damage the developing cochlea and delicate auditory structures, especially the hair cells of the cochlea, ultimately resulting in hearing loss.[66]

A more immediate effect of noise is arousal and disruption of normal sleep cycles, which are detrimental to the developing neonate in many ways.[47] Loud transient noise has been shown to cause immediate physiologic effects such as increased heart rate, blood pressure, and respiratory rate; apnea and bradycardia; hypoxia; and increased intracranial pressure.[67]

High noise levels in NICUs affect staff and families as well as infants, elevating the stress level in an already stressful environment. Much of the therapy provided in the NICU is noisy, making it difficult to facilitate developmentally beneficial auditory stimuli. These high noise levels are often a result of underlying heating, ventilation and air conditioning system, therapeutic equipment, alarms, nonacoustical surfaces, and communication devices (ie, telephones, pagers, overhead speaker systems, etc) but also results from talking and loud laughter. Sound levels in the NICU vary based on the hour of day and are often related to activities such as shift change and medical rounds.[68]

Noise levels in the infant care spaces shall not exceed 55 dB. Single-family rooms and larger clinical patient areas help reduce environmental noise because sound transmission declines geometrically as distances are increased; therefore, noise levels in these areas shall not exceed 50 dB.[69] Achieving these desired sound levels can help facilitate infant sleep and allow the baby to hear human voices at normal conversations.[70]

Awareness of the impact of increased census and equipment on sound levels can influence health care personnel's ability to provide environmentally appropriate care to premature infants. Eliminating radios and all other unnecessary sounds, transferring infants from warmers to incubators with quiet motors as soon after admission as possible, covering incubators with thick quilt/blankets made of sound-absorbent material, padding trash can lids and cupboard doors, choosing quiet paper towel dispensers, dampening phone ringer volumes, and turning pagers to vibrate mode will also assist with sound abatement.

Music therapy has been used in some units to provide a calm and soothing effect on the environment. There is not enough evidence to recommend what source, type, intensity, or duration of music may be beneficial to preterm infants. With such an emphasis on the need to achieve the quietest possible environment for the developing neonate, there is much uncertainty about the potential use of music therapy in the NICU.

Use of a decibel monitoring system can help alert staff and parents to sounds that exceed a reasonable level. By far, the most modifiable source of noise in the NICU is that generated by staff. Neonatal intensive care unit staff should be educated about the importance of keeping voice volumes low, and conversations should be held away from the bedside whenever possible. Staff should model appropriately quiet speaking tones to parents and visitors and explain the reasons why creating a quiet environment is so critical for the healing, growth, and normal development of NICU babies. In addition to education and modeling, use of a decibel monitoring system can help alert staff and parents to sounds that exceed a reasonable level.

Light

Visual problems continue to be common among NICU graduates who were born prematurely, underlying the importance of protecting the development of the visual system. Three main areas of care in the NICU that can adversely affect visual development include interference with endogenous brain cell activity, sleep deprivation, and intense light exposure.

Endogenous brain activity stimulation (activity independent) begins by spontaneous firing of neural cells in the retina and prepares the retina and visual cortex for exogenous or outside stimulation. At 29 to 30 weeks' gestation, sleep cycles consist of rapid eye movement (REM) and non-REM (NREM; slow-wave) sleep with transition to regular sleep occurring around 30 to 34 weeks' gestation.[47] Protecting sleep cycles and, especially, REM sleep periods is critical for healthy visual development because any event or drug that disrupts REM sleep can impact visual development.

At 40 weeks' gestation, the human visual system has intact retinal development and pathways to the visual cortex. It is at this time that the visual system must have regular visual stimulation. Visual experiences for healthy visual development require ambient light (not direct light), focus, attention, novelty, movement, and, after 2 to 3 months, color.[47] Because the visual system develops in utero in the total absence of light, the visual system is not developmentally ready for external visual stimuli and visual stimulation is not required at any point before term gestation. The eyelids and iris control the amount of light entering the eye. Infants at or before 32 weeks' gestation have thin eyelids and little or no pupillary constriction, often allowing developmentally inappropriate light to reach the retina.[71,72]

Lighting in the NICU should be individually adjusted to support each infant's best sleep and awake organization in accordance with their developmental stage. Ambient lighting levels in the infant care spaces shall be adjustable through a range of at least 1-feet to no more than 60-feet candles. Procedural lighting should be available at each bedside to allow caregivers to evaluate a baby or to perform a procedure. When possible, independent controls should be used to accommodate sleeping infants and working nurses, making it possible to deliver care without impinging on the development, comfort, and care of other infants.[52,65]

Although there should be a balance between dimmed ambient lighting, natural lighting, and brighter task lighting, a baby should never be positioned facing directly into any light source. Only indirect ambient lighting should be used for preterm infants who cannot block light out through their thin eyelids, cannot yet constrict their pupils, may not be able to turn away from light, and cannot communicate their needs.[69]

Lighting should be adjusted according to the infant's developmental stage. The focus of care for preterm infants 22 to 28 weeks' gestation and/or VLBW infants should be on protecting the eyes from direct light and keeping ambient light exposure to low levels. Care of the 28 to 36 weeks' gestation preterm infants should focus on protecting sleep cycles, especially REM sleep. During this time, intense stimulation from NICU noises, vibrations, and other disturbing stimuli of other sensory systems can greatly interfere with the processes of visual system development.[41]

Core Measure 2: Partnering With Families

The second neuroprotective core measure described in the Neonatal Integrative Developmental Care Model is the “Partnering With Families.” After providing a healing environment, the most important factor impacting developmental outcomes of the premature infant is family involvement. The admission of an infant to the NICU is usually a crisis for the family. The preterm delivery is often unexpected, the family unit is separated, their newly born infant is in the NICU (a place many parents did not even know existed before this event), and normal parent-infant bonding is forever altered. For most parents, the NICU is an alien environment, and their first experience in the NICU is usually a profound shock. Their infant is attached to wires, cables, and equipment in a place that is far different from the newly decorated home nursery they had planned.

The NICU environment, however, can become comforting and inviting with attentive and compassionate caregivers who welcome parents to the bedside of their infant; teach them how to understand their baby's behavioral cues and how to provide developmentally appropriate positioning and handling; provide active listening as parents process their shock, anger, and grief over the loss of a normal pregnancy and/or normal healthy term infant; and help them heal the wounds of interrupted bonding with their infants. The concept of partnering with families in the NICU includes a philosophy of care, which acknowledges that over time, the family has the greatest influence over an infant's health and well-being. The family is integral to developmental care. Indeed, development care cannot occur without the family.

All families, even those who are struggling with difficulties, bring important strengths to their infant's experiences in the NICU. Parents must be viewed as vital members of the caregiving team and as partners in the care of their infant, rather than visitors to the NICU, and should be given 24-hour access to their infant. Individualized family-centered developmental care is a framework for providing care that enhances the neurodevelopment of the infant through interventions that support both the infant and the family unit. Effective partnerships must be based on mutual respect and value family expertise, fully shared information, and joint decision making.[73]

Creating an effective partnership between professionals and families has shown benefits such as decreased length of stay, increased satisfaction for both staff and parents, and enhanced neurodevelopmental outcomes for infants[74] Establishing family-professional partnerships in the NICU environment can be challenging; however, family-centered care is recognized as a best practice that includes respect, information sharing, collaboration, and confidence building.[75]

Because families are the constant in the infant's environment, helping families achieve a positive outcome from their NICU experience should be a priority.[76] Equilateral respect among all members involved in the partnership will promote optimal patient care, enhance family satisfaction, and engage the health care team in ways that increase job satisfaction and a sense of fulfillment.

Core Measure 3: Positioning and Handling

The third neuroprotective core measure of the Neonatal Integrative Developmental Care Model is “Position and Handling.” In utero, the infant is contained in a circumferential enclosed space with 360° of well-defined boundaries. The brain of a fetus during the third trimester of gestation is undergoing rapid development as cortical neurons layer, organize, specialize, migrate, and form vital connections and pathways. The formation of synaptic connections at this stage is vulnerable to both environment and experiences. The protection afforded by the consistency of the womb allows a much more controlled and predictable progression of this neuronal development than does the variable high-tech environment of the NICU.

In contrast, the spontaneous resting posture of a third-trimester infant in the NICU is often flat, extended, asymmetrical with head to one side (usually the right), with the extremities abducted and externally rotated.[77] These postures are partially due to the effects of gravity and the dominance of extensor tone in the premature infant. Over time, neuronal connections can be reinforced that favor this flattened, externally rotated, and asymmetrical resting posture as baseline for these infants, leading to significant developmental delays and sometimes permanent disabilities.

Therapeutic positioning in the NICU is a fundamental mainstay and can influence not only neuromotor and musculoskeletal development but also physiologic function and stability, skin integrity, thermal regulation, bone density, sleep facilitation, and brain development.[77] Motor skill development begins with postural control, which is demonstrated as the capacity to maintain body alignment and orientation during rest, body part displacement, and during active, spontaneous movement.[78] This foundational motor milestone requires tactile, vestibular, and proprioceptive input for development and maturation. Preterm infants left in unsupported extended positions frequently exhibit increased stress and agitation with decreased physiologic stability.

Secure therapeutic positioning promotes improved rest, supports optimal growth, and helps to normalize neurobehavioral organization. Body containment is an important factor because it increases the infant's feelings of security and self-control and decreases stress. Infants who are contained tend to be calmer, require less medication, and gain weight more rapidly. Despite the available and expanding body of research regarding gravity, posture, and motor development, the current state of positioning practices in the NICU lacks consistency in adoption, application, and use of effective therapeutic supportive positioning practices and positioning aids.

Intrauterine four-dimensional ultrasound footage highlights early unrestricted fetal movement and fetal postural stability enjoyed by the developing fetus as early as 8 weeks' gestation. DeVries and Fong,[79] in an elegant and thorough review of the literature of fetal ultrasonography, describe the emergence and progression of fetal motility across gestation with earliest movements noted between 7 and 8 weeks' gestation. As pregnancy advances, there is a progressive organization of fetal activities into complex and clearly distinct behavioral patterns.

The hospitalized critically ill and/or premature infant has limited energy stores and a high-energy expenditure, which is complicated by severity of illness that persists over the hospital course.[80] Pridham et al[81] revealed that motor activity played a key role in energy expenditure and suggested the implementation of developmental care strategies such as supportive positioning, minimal handling, and containment to protect energy for growth. Understanding the developmental progression of movement within the context of the intrauterine environment, energy demands during the postnatal period and the musculoskeletal/neurosensory vulnerabilities of the critically ill and/or preterm infant are requisites for the NICU clinician, providing an evidence-based reference point for developmentally supportive positioning practices.

Movement occurs in concert with tactile, vestibular, and proprioceptive input. The central and peripheral nervous systems must differentiate between vestibular signals imposed by the external world and those that result from spontaneous, self-directed actions. The critically ill and/or premature infant in the NICU receives vestibular input primarily through an external source (ie, the parent or clinician) and is consequently vulnerable to sensory distress and excessive motor movements in an effort to stabilize and orient to a fixed surface during vestibular disturbances.[82] Providing supportive proprioceptive input in the way of containment, thereby imitating the spatial limitations of the womb, has been demonstrated to positively influence neuromotor and neurosensory maturation.

Vaivre-Douret et al[83] documented the importance of frequent position changes and functional postural support enabling spontaneous motor activity for normal neuromuscular and osteoarticular function in low-risk preterm infants aged 31 to 36 weeks' gestation. The connection between motor development and neurodevelopmental outcome has been well documented in the literature and summarized by Monterosso et al[84]; NICU nurses must take special care to incorporate postural interventions when caring for VLBW infants to promote the development of optimal posture and motor skills.

Therapeutic supportive positioning devices must allow spontaneous movement, provide tactile and proprioceptive containment, and displace infant body weight to the lower abdomen and pelvis when the infant is in the prone position.[82] Providing ventral support while infants are in the prone position makes it possible to keep their shoulders rounded and hips in a flexed position.

Although positioning is very important in the NICU, the astute bedside caregiver realizes that it is not just static position that affects neurodevelopmental outcomes, but caregiving and handling of the infant, as well. Research has shown that developmental caregiving enhances the outcomes of high-risk infants who require neonatal intensive care. Handling of infants should be done with slow, modulated movements, with the infant's extremities flexed and contained. Although efficient, moving preterm infants suddenly and quickly can be a very negative and stressful experience for the infant and often results in autonomic deterioration seen by apnea, bradycardia, and/or increased oxygen requirement.

The idea of clustering care is now being modified because infants do not always tolerate all of the care that is being clustered into one caregiving period. Caregiving based on infant cues is an integral part of providing developmentally appropriate care. Infant-driven cues, rather than clustered care, should be used for optimal caregiving practices. These cues provide communication about an infant's needs and status at any given time. Caregiving based on infant cues involves attention to messages from the infant that may indicate timing for interventions or opportunities for sensory input and interaction. These cues also indicate how the infant tolerates stimuli and stimulation. Frequent handling and touching can disturb sleep, leading to decreased weight gain, decreased state regulation, and, more importantly, detrimental effects on brain development. Attention to appropriate timing of caregiving according to the infant's sleep and arousal is important because better sleep organization has been correlated with improved outcomes.[85]

Children who were born prematurely have alterations in cortical development, functional connectivity, and patterns of neural activation in response to incoming stimuli. Because of this, their capacity for neuroplasticity is reduced and may contribute to common difficulties with learning and memory.[86] A principle termed *activity-dependent development* refers to the influence of usage and repetition in formation of neural connections and pathways in the brain. It is hypothesized that if specific neurons are consistently fired together, they are strengthened and become dominant, causing a hardwiring for that response. In contrast, neurons that are not used or fired develop a weak neuronal connection, or may even disappear. Therefore, the consistency of the environment can strengthen or weaken a neuronal response.

A preterm infant, when handled for reasons such as diaper change, bathing, feeding, or for diagnostic or therapeutic procedures, can react negatively for several minutes until he or she becomes exhausted. This results in an unnecessary expenditure of energy that can, at a later time, turn into physiologic (bradycardia, tachycardia, drop in oxygen saturation, and apnea) or behavioral (flaccidity, fatigue, and difficulty sleeping) instability and signs of distress and pain. A gentle method of handling and caregiving, such as swaddled bathing, can improve these instabilities. Not only does swaddled tub bathing promote more organized infant behavior, infants also show overall higher and less variability in body temperature.[87]

Forming a "nest" with soft boundaries provides postural, behavioral, and physiologic stability to the newborn. Comaru and Miura[88] researching postural support in preterm infants demonstrated that although all babies displayed increased distress and pain scores during diaper changes, this was statistically less for babies nested compared to nonnested babies. Activity-dependent development is important to consider with the constant repetitive activities performed in the NICU by the bedside caregiver. This principle encourages the bedside caregiver to adapt all caregiving behaviors to alleviate as much aversive or negative sensory input from caregiving activities as possible.

Nurses control caregiving routines by collaborating effectively with other disciplines to negotiate timing, intensity, and appropriateness of interventions, tests, and procedures. Continuous observation and response to infant cues require nurses to alter care routines according to developmentally supportive principles.[89] A paradigm shift from task-oriented and scheduled care to infant-responsive care must occur to achieve optimal caregiving practices. The nurse must stay in the "present" and be "mindful" when interacting with the infant.

Skin-to-skin care, or kangaroo care, is the practice of holding a diaper-clad newborn or preterm infant on a parent's bare chest in an upright prone position and is considered an appropriate developmental plasticity intervention.[90] This practice has been shown to foster optimal autonomic and physiologic stability, supports motor development, and stabilizes sleep cycles, which promotes optimal brain development, healing, and growth. Kangaroo care improves maternal-infant bonding, increases feeding tolerance, reduces infection rates, supports thermoregulation, and minimizes stress and pain.[91]

Developmentally supportive positioning in the NICU, with the inherent goal of replicating the supportive, contained, nongravitational environment of the uterus, is essential for optimal musculoskeletal development. Developmentally supportive positioning has also been shown to have an array of physical, social, and psychological benefits that last beyond the neonatal period. Health care providers, parents, and consumers are no longer satisfied with minimum standards of care provision. Quality care with attention to comfort, developmental trajectory of the infant, and family integration is the new standard of care in NICU's around the world.

Core Measure 4: Safeguarding Sleep

The fourth neuroprotective core measure of the Neonatal Integrative Developmental Care Model is "Safeguarding Sleep." Sleep is an extremely important issue for the infant in the NICU. At approximately 28 weeks' gestation, individual sleep patterns begin to emerge characterized by REM and NREM sleep periods. These periods become constant by 36 to 38 weeks' gestational age. Rapid eye movement sleep dominates in the initial sleep cycles; REM and NREM are nearly equal as the infant approaches term, and by 8 months of age, NREM sleep occupies nearly 80% of sleep time.[92] Both REM and NREM sleep cycles are essential for early neurosensory development, learning and memory, and preservation of brain plasticity for the life of the individual.[47]

Endogenous (arising from neurons within the neurosensory system) and exogenous (arising from outside the neurosensory system) stimuli are essential for neurosensory development. Patterns of endogenous stimulation occur only during REM sleep, thus making this period essential to the process of endogenous stimulation and the development of neurosensory systems. Once endogenous neurosensory systems are developed, they are readied for exogenous stimulation. For the visual system, the need for visual experiences does not occur until near-term or 40 weeks' gestational age.[71] The environment of the fetus in utero and the preterm infant in the NICU requires appropriate levels of specific types of exogenous neurosensory stimuli for healthy early brain development.[47,85]

Preservation of "brain plasticity," the ability of the brain to constantly change its structure and function in response to environmental changes, is an essential process throughout childhood and adult life. Sleep deprivation (both REM and NREM) results in a loss of brain plasticity, which is manifested by smaller brains, altered subsequent learning, and long-term effect on behavior and brain function. Facilitation and protection of sleep and sleep cycles are essential to long-term learning and continuing brain development through the preservation of brain plasticity.[93]

Because REM sleep is essential for neurosensory and visual development, neuroprotective strategies for the NICU infant are as follows:

- Protect sleep cycles and, especially, REM sleep. Avoid sleep interruptions, bright lights, loud noises, and unnecessary physical disturbing activities.
- Protect the eyes from direct light exposure and maintain low levels of ambient light when not needed for care and procedures.
- Provide some daily exposure to light, preferably including shorter wavelengths, for entrainment of the circadian rhythm. Protect sleep cycles and, especially, REM sleep.
- Avoid high doses of sedative and depressing drugs that can depress the endogenous firing of cells, thus interfering with visual development, REM, and NREM sleep cycles and, thus, optimal brain development.
- Provide developmental care appropriate for the age and maturation of the infant.[71]

Continuous bright lights (as well as loud sounds) in the NICU can disrupt sleep-wake states. Patients of any age who are trying to sleep find direct light unpleasant. Premature infants are photophobic; however, they will open their eyes with dim lights. If the light levels never change, infants never experience the diurnal rhythm necessary for development. Reducing light (and sound) levels will facilitate rest and subsequent energy conservation and promote organization and growth.

Core Measure 5: Minimizing Stress and Pain

The fifth neuroprotective core measure of the Neonatal Integrative Developmental Care Model is "Minimizing Stress and Pain." From the first moments after birth, the premature infant is subjected to noxious sounds, bright lights, and a multitude of painful procedures along with repetitive, nonnurturing handling and separation from mother. Seemingly typical handling and caregiving by the NICU staff such as bathing, weighing, and diaper changes are perceived as stress to the infant.[88,94] This altered sensory experience is inherently stressful and has negative effects on the infant's brain development.

Consequences of neonatal stress include increased energy expenditure, decreased healing and growth, impaired physiologic stability, and altered brain development. Neonatal intensive care unit stressors and painful interventions may raise cortisol levels, limiting neuroplastic reorganization and therefore learning and memory of motor skills. Infants who are exposed to repeated painful experiences can have negative short- and long-term consequences for brain organization during sensitive periods of development.[95,96]

Minimizing stress in preterm infants may have many neurologic benefits such as reducing the likelihood of programming abnormal stress responsiveness, which will help preserve existing neuroplastic capacity.[97] Infants have demonstrated markedly improved outcomes when the stress of environmental overstimulation is reduced. As we continue striving to improve morbidity and mortality rates, we are challenged to enhance neuroprotective strategies for these vulnerable infants.

Core Measure 6: Protecting Skin

The sixth neuroprotective core measure of the Neonatal Integrative Developmental Care Model is "Protecting Skin." Immature skin structures of premature infants are very different than the skin of full-term infants. Skin care practices outlining bathing practices, emollient usage, humidity practices, and use of adhesives for babies in each stage of development should be incorporated into unit practices and policies.

Functions of the skin include thermoregulation; fat storage and insulation; fluid and electrolyte balance; barrier protection against penetration and absorption of bacteria and toxins; sensation of touch, pressure, and pain; and conduit of sensory information to the brain. Three major layers of the skin are the epidermis, the dermis, and subcutaneous layer. The epidermis is the outer layer that contains the stratum corneum. An infant born at 23 weeks' gestation has virtually no stratum corneum and, by 32 weeks' gestation, has only a few layers. The epidermis, more specifically the stratum corneum, is the most important permeability barrier in the skin.[98]

The epidermis is attached to the dermis by protein fibrils and contains nerves that carry sensation from the skin to the brain and blood vessels that nourish the skin. The dermis is elastic and resilient, whereas the subcutaneous layer consists of fatty connective tissue that provides insulation and stores calories but is not deposited until the last trimester of pregnancy.[34] The stratum corneum in premature neonates older than 27 weeks matures at an accelerated rate the first 2 weeks of life.[99] When skin dries out after birth, it is a part of the skin's natural maturational process. Any interference of this process (ie, lotions or creams) delays the development of the stratum corneum and prolongs problems associated with an immature stratum corneum.[34]

The underdeveloped stratum corneum (SC) causes preterm infants to be at risk for increased transepidermal water loss (TEWL) through the epidermis.[100] In addition, the ratio of large surface area to body weight and increased blood supply that is closer to the skin surface also increase TEWL and heat loss.[34] The use of emollients is controversial without conclusive evidence for use or nonuse. Emollients may interfere with the skin drying process after birth, which is part of the natural maturation process of the SC. Emollients have also been linked to an increase in hospital-acquired infections (both bacterial and fungal).[98] As an alternative to emollients, providing humidity of more than 70% inside the incubator for the first 2 weeks of life has been shown to decrease TEWL[100] in the extremely-low-birth-weight (ELBW) infant.

At the moment of birth, the skin is sterile, and within 24 hours, it has been colonized with its own bacteria.[98] An acid mantle with a pH of less than 5 is created by the skin to protect from microorganisms. The pH of a full-term infants' skin is neutral at birth and falls to 5 within 1 week of life; yet the skin of 24- to 34-week-old infants has a pH of 6 at birth, which does not fall to 5 until 3 weeks of life.[99,101,102]

Bathing of a premature infant can have detrimental effects including hypothermia, unstable vital signs, absorption of harmful chemicals, and pH changes with disruption of the acid-base mantle. Protection of the skin can be facilitated in less than 1000-gram infants by bathing every 4 days using only water.[99,103,104]

Although the use of adhesives in the NICU is unavoidable, the amount of tape used should be limited whenever possible and the use of newer hydrogel-based adhesives should be evaluated. Gentle care should be used whenever tape is removed because this is often a painful procedure for infants. By using the most evidence-based skin care guidelines available along with careful monitoring and gentle, consistent care, improved skin outcomes can be realized.

Core Measure 7: Optimizing Nutrition

The seventh neuroprotective core measure of the Neonatal Integrative Developmental Care Model is "Optimizing Nutrition. " Scientific evidence overwhelmingly indicates that breastfeeding is the optimal method of infant feeding and should be promoted and supported to ensure optimal nutrition in infants. Breastfeeding is the single most powerful and well-documented preventive modality available to health care providers to reduce the risk of common causes of infant morbidity. Because breast milk is the most well-tolerated substrate for enteral feedings in the premature infant, full enteral feedings are reached sooner when breast milk is used, thereby decreasing the total days of total parenteral nutrition needed and the potential for total parenteral nutrition–induced adverse effects.[105]

The protective properties of breast milk cannot be duplicated. Significantly decreased risks of necrotizing enterocolitis, sepsis, and retinopathy of prematurity have been demonstrated when breast milk is used for enteral feedings. Increased IQ, improved neurodevelopmental outcomes, and larger brain volume have also been found in preterm infants fed breast milk. Because of the many well-documented benefits of human milk for the preterm infant, supporting mothers in the initiation and maintenance of adequate breast milk supply should be a major focus in the NICU.

Even when adequate breast milk is available and with successful breastfeeding, most premature neonates learn to eat via nipple feeding. Nipple feeding is a complex task for premature infants and requires a skilled caregiver to assist the infant to achieve a pleasurable feeding experience. The use of infant-driven feeding scales that address feeding readiness, quality of nippling, and caregiver interventions used are beneficial when initiating oral feeds in the premature neonate. Goals for successful infant-driven feedings are that oral feedings should be safe, functional, nurturing, and individually and developmentally appropriate.[106] Immature feeding is a common reason for prolonged hospital stays for premature infants, and persistent poor feeding can result in hospital readmissions. Maturational and developmental issues in premature infants affect oral feeding success because only 53% of brain cortical volume is present at 34 weeks' gestation when an infant is just beginning oral feeds.[107] Educating staff and parents about infant cues and specialized feeding techniques is essential because they are the foundation for continued success and prevention of future oral aversion.[108]

Providing support for breastfeeding mothers in learning to feed their preterm infants at the breast, as well as learning to feed with a bottle (with expressed breast milk or preterm formula), is important and should not be left for the day of discharge. Daily skin-to-skin holding can facilitate early "practice" breastfeeding sessions for mothers and babies. Assuring that breastfeeding infants are competent and mothers are comfortable with breastfeeding well before discharge should be a priority.

Summary

As the preterm infant matures, the NICU environment where the infant resides plays a critical role in their future development. High-risk infants are both dependent on and vulnerable to the NICU environment. Although dependent on the NICU for the maintenance of their physiologic functions while recovering from the insult of being born too soon, they are also vulnerable to all the stressors inherent in fetal development occurring outside the womb in the artificial environment of the NICU. As the preterm infant matures, the quality of the environment in which the infant resides plays a critical role in the trajectory of recovery, growth, and development.

Learning the principles of neurodevelopment and understanding the meaning of preterm behavioral cues make it possible for the NICU caregiver to provide individualized developmentally appropriate, neuroprotective care to each infant. Partnering with families and restoring parent-infant attachment set the stage for emotional stability. Providing gentle containment, supportive boundaries, and flexed positions help to simulate the womb that was lost prematurely. By minimizing stress and pain, safeguarding sleep, protecting skin, and optimizing nutrition, NICU caregivers can enhance the daily experience of the infants in their care and increase the chances of achieving optimal physical, cognitive, and emotional outcomes.

The seven core measures of the Neonatal Integrative Developmental Care Model provide specific guidance in achieving these goals. To consistently improve and standardize neonatal practice, these measures allow for quantification of data that are typically subjective and make possible comparative analysis when benchmarking and comparing individual organizations with themselves or multiple organizations with each other.

Changes in developmental care can often begin with a few motivated caregivers altering the way they care for premature infants. Role modeling, mentoring, and collaboration are keys in the promotion of optimal developmental care. An overarching goal is to achieve an effectively healing, peaceful, and satisfying environment for NICU staff, families, and the infants entrusted to our care.

Developmentally supportive care is sometimes perceived as “nice,” yet optional. It is sometimes thought of as “fluff” in a primarily technologically driven environment. Ignorance of or dismissal of the growing body of evidence about the importance of providing neuroprotective care for preterm infants is no longer acceptable. Consistent acceptance, practice, and accountability must be established to provide the high-quality care every infant and family deserves. Use of established guidelines, policies, and procedures to guide neonatal practice is essential. Health care professionals must be cognizant of the growing body of research regarding the impact of the NICU environment on neurodevelopmental outcomes.[109] “Focusing on respect for the fragile human being and his or her family not only is essential for the further improvement of medical care and developmental outcome…but is important from a humane point of view.”[110] As Dr Seuss so quaintly pointed out, “A person is a person no matter how small.”[111]

Appendix A: Neuroprotective Interventions Related to the Seven Core Measures of Neuroprotective Care

Core measure 1: Healing Environment		
Standard: A policy/procedure/guideline on the Healing Environment including physical space and privacy as well as the protection of the infant's sensory system exists and is followed throughout the infant's stay		
Infant Characteristics	Goals	Neuroprotective Interventions
Stability of the infant's autonomic, sensory, motoric, and state regulation systems	An environment will be maintained that promotes healing by minimizing the impact of the artificial extrauterine NICU environment on the developing infant's brain.	Space: • Maintain a private and safe environment for the infant and family that consists of a minimum of 120 sq ft per patient. Tactile: • Provide soft, gentle touch in all caregiving interactions. • Facilitate skin-to-skin care as soon as possible after birth and then daily by either parent (or caregiver designated by parent). • Provide a neutral thermal environment for the infant incorporating the following factors: - If ELBW, provide incubator humidity during the first 2 wk after birth. - Provide care in incubator until infant can maintain own temperature. Vestibular: • Change infant's position slowly with no sudden movements. Olfactory: • Maintain a scent-free and fragrance-free unit. • Facilitate early, frequent, and prolonged skin-to-skin care. • Provide the mother's scent when possible via breast pad, soft cloth, or Snoedel. Gustatory: • Position infant with hands near face • Provide colostrum or expressed breast milk (EBM) oral care per protocol. • Provide positive oral feeding experiences as outlined in the "Optimizing Nutrition" section. Auditory: • Monitor sounds levels to maintain sound levels of <50 dB. • Turn off alarms as quickly as possible. Visual: • Provide adjustable light levels up to a maximum of 60 ftc. • Cover infant's eyes during every examination.

Core measure 2: Partnering With Families		
Standard 1: A policy/procedure/guideline on family-centered care exists and is followed throughout the infant's stay. Standard 2: There is a specific mission statement addressing family-centered developmental care		
Infant Characteristics	Goals	Neuroprotective Interventions
Infant's response to parental interactions	Parents will be viewed not as "visitors" but as vital members of the caregiving team with 24-h/d access to their baby. Parents will be supported in their role as the most important caregivers for their infant. Infant will develop secure attachment with parents.	• Acknowledge where the family is in regard to stages of grief and loss and provide individualized and appropriate resources as needed. • Actively listen to families' feelings and concerns (both verbal and nonverbal). • Communicate the infant's medical and developmental needs in a culturally appropriate and understandable way. • Facilitate early, frequent, and prolonged skin-to-skin care. • Educate parents on how they can participate in the care of their infant at the level they desire whenever desire. • Assist parents in becoming competent in caring for their baby. • Encourage parents as they develop confidence in their own abilities to continue providing care for their baby after going home.

Core measure 3: Positioning and Handling		
Standard: A policy/procedure/guideline on positioning and handling exists and is followed throughout the infant's stay		
Infant Characteristics	Goals	Neuroprotective Interventions
Autonomic stability during handling	Autonomic stability will be maintained throughout positioning changes and handling activities as well as during periods of rest and sleep.	• Anticipate, prioritize, and support the infant's individualized needs during every caregiving interaction to minimize stressors known to interfere with normal development.
Ability to maintain tone and flexed postures with and without supports	Preventable positional deformities will be eliminated or minimized by maintaining infants in a midline, flexed, contained, and comfortable position throughout their NICU stay.	• Use a validated and reliable positioning assessment tool (ie, Infant Positioning Assessment Tool [IPAT]) routinely according to hospital protocol.
	The caregiver sees her or himself in partnership with the baby so that caregiving procedures are performed "with" the infant rather than "to" the infant.	• Maintain a midline, flexed, contained, and comfortable position at all times using appropriate positioning aids and boundaries.
	Infants will be provided developmentally appropriate stimulation/play as they mature (ie, mobiles, swings, etc)	• Provide appropriate prone support to ensure flexed shoulders and hips. • Assess infant sleep-wake cycle to evaluate appropriate timing of positioning and caring. • Reposition infant with cares and minimally every 4 h. • Provide 4-handed support during positioning and caring activities. • Provide swaddling when bathing and weighing • Promote hand to mouth contact. • Educate parents about the principles and techniques of positioning, containment, and handling.

(continued on next page)

(*contunued*)

Core measure 4: Safeguarding Sleep

Standard: A policy/procedure/guideline on safeguarding sleep and back-to-sleep practices exists and is followed throughout the infant's stay

Infant Characteristics	Goals	Neuroprotective Interventions
Infant sleep-wake states, cycles, and transitions Infant's maturity and readiness for Back-to-Sleep Protocol	Infant sleep-wake states will be assessed before initiating all caregiving activities. Prolonged periods of uninterrupted sleep will be protected. Infants will be transitioned to Back-to-Sleep Protocol when developmentally appropriate.	• Individualize all caregiving activities by clustering cares based on infant sleep-wake states. • Pay close attention to infant signs of stress during clustered cares. • If necessary to arouse a sleeping infant, approach using a soft voice followed by gentle touch. • Facilitate prolonged skin-to-skin care to promote normal sleep patterns. • Use incubator covers to protect the infant from direct light. • Promote a quiet environment to ensure uninterrupted sleep. • Assure infant is able to maintain normal sleep pattern during back-to-sleep well before discharge and role model this behavior. • Provide tummy time/prone-to-play time routinely for infants that are back-to-sleep. • Educate parents about the importance and rationale for back-to-sleep and tummy time.

Core measure 5: Minimizing Stress and Pain

Standard: A policy/procedure/guideline on the assessment and management of pain exists and is followed throughout the infant's stay.

Infant Characteristics	Goals	Neuroprotective Interventions
Behavioral cues indicating stress or self-regulation	Promote self-regulation and neurodevelopmental organization	• Provide individualized care in a manner that anticipates, prioritizes, and supports the needs of infants to minimize stress and pain. • Use a validated and reliable pain assessment tool routinely according to hospital protocol. • Provide nonpharmacologic support (positioning, containment, swaddling, pacifier, and sucrose) with all minor invasive interventions. • Use pain assessment tool to evaluate the need for pharmacologic support. • Involve parents in supporting their infant during painful procedures if they choose by assisting with containment or by providing skin-to-skin holding. • Educate parents on how to read their infant's behavioral cues related to stress and pain and how to provide comforting interventions.

Core measure 6: Protecting Skin

Standard: A policy/procedure/guideline on skin care exists and is followed throughout the infant's stay

Infant Characteristics	Goals	Neuroprotective Interventions
Maturity and integrity of infant skin	Reduce TEWL of ELBW infants Maintain skin integrity of the infant from birth to discharge Provide developmentally appropriate infant massage	• Provide individualized care in a manner that anticipates, prioritizes, and supports the needs of infants to optimize neuromotor development. • Use a validated and reliable skin assessment tool (ie, Braden Q) on admission and routinely according to hospital protocol. • Provide humidity for ELBW infants during the first 2 wk after birth. • Provide appropriate positioning using gel products to prevent skin breakdown. • Minimize use of adhesives and use caution when removing adhesives to prevent epidermal stripping. • Avoid soaps and routine use of emollients. • Provide full-body swaddled bathing no more than every 72–96 h. • Use water only for bathing $<$1000-g infants. • Use pH neutral cleansers for bathing $>$1000-g infants. • Educate parents on skin care, swaddled bathing, and delivery of developmentally appropriate infant massage.

Core measure 7: Optimizing Nutrition

Standard 1: A policy/procedure/guideline on optimizing nutrition (cue-based/infant-driven breast or bottle feeding, which includes infant readiness, quality of nippling, and caregiver techniques) is followed throughout the infant's stay

Standard 2: A policy/procedure/guideline on skin-to-skin care (kangaroo care) exists and is followed throughout the infant's stay

Infant Characteristics	Goals	Neuroprotective Interventions
Physiologic stability with handling and feeding	Feeding will be safe, functional, nurturing, and developmentally appropriate.	• Individualized care by incorporating cue-based/infant-driven feeding practices
Feeding readiness cues	Optimized nutrition will be enhanced by individualizing all feeding care practices.	• Facilitate early, frequent, and prolonged skin-to-skin care.
Coordinated suck/swallow/breathing throughout breasfeeding or bottlefeeding	Oral aversions will be prevented by assuring is a positive experience for infant.	• Support mother's EBM supply.

(*continued*)

Core measure 7: Optimizing Nutrition		
Standard 1: A policy/procedure/guideline on optimizing nutrition (cue-based/infant-driven breast or bottle feeding, which includes infant readiness, quality of nippling, and caregiver techniques) is followed throughout the infant's stay		
Standard 2: A policy/procedure/guideline on skin-to-skin care (kangaroo care) exists and is followed throughout the infant's stay		
Infant Characteristics	Goals	Neuroprotective Interventions
Endurance to maintain nutritional intake and support growth	Infants of breastfeeding mothers will be competent at breast feeding before discharge.	• Minimize negative perioral stimulation (adhesives, suctioning, etc). • Use indwelling gavage tubes rather than intermittent tubes. • Promote nonnutritive sucking (NNS) at mother's pumped breast during gavage feeds. • Hold infant and use NNS with appropriate-sized pacifier during gavage feeds when mother is not available. • Provide the taste and smell of breast milk with gavage feedings. • Once orally feeding, focus on quality of feeding experience vs quantity of feeds. • Use caregiver techniques when nippling infant to avoid twisting, jiggling, excessive chin and neck support, and so on. • Promote side-lying position close to parent/caregiver when bottle feeding. • Educate parents about infant feeding cues. • Support breastfeeding mothers in feeding infant at the breast.

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